Appendix D - Clarification of Some Basic Issues with Regard to Delta Levees (Chapter 4)

Contents

Variability

Because of their location in the Delta and their history of construction, Delta levees have rather variable foundation conditions and composition. This makes it difficult and expensive to conduct detailed geotechnical engineering investigations and analyses. Although the DRMS Phase 1 report refers to a large number of soil borings that have been conducted, most of these are older borings that have limited value with respect to engineering properties because insufficient testing was carried out. While the lack of hard engineering data on the properties of the levees is problematic, the levee system has, in fact, been proof loaded for 100 years or more. The "observational method" is a well-recognized procedure in geotechnical engineering and is particularly applicable to uncertain foundation condition and variable material properties. The history of the Delta levees shows that although there were many levee failures in earlier years, the majority of those resulted from overtopping. Improved flood management, in addition to other improvements in the levees, has significantly reduced the rate of failure. Today's levees, which retain water 24 hours a day, have demonstrated an ability to withstand normal tidal and typical flood loadings regardless of their variability. While there is seepage through these levees, it is acceptable as long as the seepage is controlled. Another basic principle in geotechnical engineering is, "You don't need to stop all seepage, you just need to control the seepage."

One of the variables associated with Delta levees is the depth of peat. The depth of peat under the levees is not necessarily the same as the depth of peat that remains in the center of the islands. This second number is now much lower as a result of loss of peat due to oxidation and erosion. However, the loss of peat under the levees themselves has been limited.

While there is great variation in "typical" Delta levees, the cross section of the existing levee on Webb Tract shown in Figure 4.19 is likely typical of many levees in the western and central Delta where the man-made levees are not constructed over natural levees and the height of the levee as seen from the land side is the result of subsidence of the land surface rather than the building up of the levees. As can be seen in this cross section, the levee is actually composed largely of peat rather than fill. That is both good and bad. As discussed below, it is good because peat is not susceptible to liquefaction and might be expected to perform well in earthquakes; however, peat is relatively weak and very compressible, so that placement of any additional fill must be handled very carefully. The other two kinds of levee section that might be referred to as typical apply to those levees built on top of natural levees, as shown in Mount and Twiss (2005),[1] and those levees in the north and south Delta that generally consist of more sandy materials constructed on sandy foundations. The depositional history and geology of the sands that underlie the Delta has been studied in detail by Shlemon and Begg (1972)[2] and Atwater (1982).[3] While they are variable in origin, these sands generally provide a good foundation for any structures that they support. The common suggestion that Delta levees are founded on poor materials or "quicksand" is less than accurate.

[1] Mount, J.F. and R. Twiss (2005), "Subsidence, sea level rise, seismicity in the Sacramento-San Joaquin Delta," *San Francisco Estuary and Watershed Science*, v. 3, article 5, 2005.
[2] Shlemon, R.J. and E.L. Begg (1975), Late Quaternary evolution of the Sacramento–San Joaquin Delta, California. *Quaternary Studies*, 13: 259-266.
[3] Atwater, B. (1982), Geologic Maps of the Sacramento–San Joaquin Delta, California, USGS Miscellaneous Field Studies Map MF-1401.

Vulnerability to tides and floods

Delta levees are vulnerable to more extreme tides and floods and particularly adverse combinations of these two loadings. There were no significant Delta levee failures in the 1997 flood, said to be a 100-year or greater flood; however, widespread failure of levees upstream from Stockton reduced the maximum water surface elevations in the Delta. But, this type of relief should also be component of a planned flood management system so that there is a limit to the hazard posed not only to Delta levees but to the levees protecting Sacramento and Stockton as well. High water elevations resulting from tides and floods can also be seen days or weeks in advance so that appropriate emergency measures can be taken. The probabilities of failure due to overtopping that are calculated in DRMS appear to be inconsistent with these realities.

Impacts of subsidence and sea-level rise

Land subsidence in the Delta is real, but its continuing significance is often overstated. The historic subsidence due to oxidation and erosion of the peat has been well-documented by Mount and Twiss. As noted by Mount and Twiss, the post-1950 subsidence rates were reduced by 20 to 40 percent from early rates as a result of better farming practices. Although they recognized that subsidence rates will slow further due to depletion of organic material and the continuation of better land-use practices, they still used the upper bound of this range in making projections going forward to 2050. Interpretation of the 2007 DWR LiDAR data by MBK Engineers, as reported in comments to the Delta Stewardship Council by the Central Valley Flood Control Association (2011),[4] suggest that over the last 30 years little if any subsidence has occurred in areas that are currently higher than 10 feet below sea level. In fact, problems associated with subsidence, such as impaired drainage, are only occurring on lands currently below 12 to 15 feet below sea level. MBK's studies indicate that only about 96,000 acres, or 14 percent of the area of the Delta, lies below minus 12 feet and that only 57,000 acres, or 8 percent of the total area, lies below minus 15 feet. These figures suggest that continued subsidence is not a Delta-wide problem.

Subsidence of even several additional feet has relatively little impact on the stability and seepage issues associated with levees that are already 20 to 30 feet high on the land side. Likewise, although sea-level rise of 5 feet would have some impact on the stability and seepage issues associated with the current levees, it would have little consequence for levees improved to the suggested Delta standard and even less consequence for sea-level rise that is consistent with the probability of occurrence of the water surface elevations and earthquake loadings for which these levees will be designed.

Vulnerability to earthquakes

Delta levees also have some vulnerability to earthquakes but coverage in popular media and discussion in political debates has often over-stated the risk of earthquake-induced levee failure and regrettably this kind of over-statement was echoed in the Delta Stewardship

[4] California Central Valley Flood Control Association, Comments on Flood Risk White Paper, Delta Stewardship Council, January 2011.
http://www.deltacouncil.ca.gov/sites/default/files/documents/files/CVFCA_012011_0.pdf

Council's Flood Risk White Paper.[5] However, the seismic risk portion of DRMS was relatively well done and the results shown in Figure 5.14 of the White Paper can serve as a useful starting point for an intelligent discussion of earthquake-induced failure of levees. This figure indicates that the 100-year return period peak ground acceleration (pga) in the Delta ranges from 0.1 to 0.2g in firm soils. The phenomenon of liquefaction is generally cited as the greatest contributor to the hazard faced by the Delta levees, and this level of acceleration is lower than that which has been observed to trigger liquefaction in hydraulically-placed dams and sand fills. The examples of liquefaction-induced failures that are shown in Figures 5.8 to 5.13 are not applicable to the Delta because the subsurface conditions in the Delta are unique and unlike those of the case histories shown in these figures.

There are three different situations where loose sands that may be susceptible to liquefaction are found in and under the Delta levees. One possible source of loose sands is the natural levees that underlie some of the present-day levees. The extent of this condition is believed to be limited, as discussed previously. The second possible source of sands that may be susceptible to liquefaction is hydraulically placed clean sand that has been dredged from the main river channels and placed in adjacent levees without compaction. The actual extent of these materials is unclear and it may be that these materials are sufficiently well drained that most of the excess pore pressures that are generated by earthquake shaking would quickly dissipate so that any deformations would be limited. The third source is the topmost sand layer that underlies the peat. As noted previously, from a geotechnical engineering point of view, the sands that underlie the Delta can, with the possible exception of the top 10 feet, be characterized as dense to very dense, and actually constitute a good foundation. Meticulous work by Drexler et al. (2009)[6] indicates that the oldest peat deposits are in the order of 7,000 years old so that the underlying sands are at least this old. That age, when combined with the penetration resistances cited by Hultgren-Tillis Engineers in their report on Webb Tract,[7] suggest that even the surficial sands are not particularly susceptible to liquefaction. Even under the 500-year return period ground motions estimated in DRMS, which range from 0.2 to 0.4g in firm soils, significant or widespread deformations from any of these three kinds of sands should not be expected. The repeated citing of levee deformations that were sustained in the Kobe and Christchurch earthquakes, which had higher ground motions and where levees were founded on very loose and recent alluvial soils, is not particularly helpful. However, although these case histories are not directly applicable to the Delta, they do illustrate that levees do not necessarily breach and release water, even when they are quite badly deformed. In fact, to the extent that the Delta levees are largely composed of peat, they may be expected to perform better than levees in general under earthquake loadings. Because of the unusual fibrous nature of peat, not only is it expected not to lose strength under earthquake loadings, but it also might be expected to attenuate ground motions with peak accelerations in the order of 0.2g or more. Thus, a fair summary would be that the risk of failure of Delta levees due to earthquake shaking cannot be dismissed, but that more detailed studies are required to determine whether it even rises to significant levels.

[5] Delta Stewardship Council (2010), Flood Risk White Paper, http://deltacouncil.ca.gov/delta-plan

[6] Drexler, J.Z., C.S. de Fontaine and T.A. Brown (2009), Peat Accretion Histories During the Past 6,000 Years in Marshes of the Sacramento–San Joaquin Delta, CA, USA, Estuaries and Coasts, 32:871–892.

[7] Hultgren-Tillis Engineers, Geotechnical Evaluation, Seismically Repairable Levee, Webb Tract, Report to Reclamation District 2026, December 2009.

Sunny-day failures

As with floods and earthquakes, the real risk of "sunny-day" failures has been overstated. The Flood Risk White Paper prepared for the Delta Stewardship Council again cites numbers from DRMS even though the IRP cautioned against taking DRMS numbers at face value. There have been three major "sunny day" failures in the last 30 years: the 1980 failure of Lower Jones Tract, the 1982 failure of McDonald Island, and the 2004 failure of Upper Jones Tract. While at first blush this is not inconsistent with the DRMS estimate of one failure every 10 years, the first two of these resulted from operation of the PG&E gas storage facility under McDonald Island. Thus, the true rate of sunny-day failures due to unknown causes is less than once every 30 years. Improvements in systems for monitoring the internal condition of levees, as discussed in Section 3.2, should allow more prompt discovery of dangerous conditions in the future and further reduce the probability of sunny-day failures.

Summation of failure mechanisms

As suggested by the discussion in the previous paragraphs, there are a number of factors that make it very difficult to precisely quantify the probabilities of single or multiple levee breaches in a given window.

The first of these factors is the variability of the existing levee system. It is not possible to accurately and meaningfully calculate the fragilities that are needed to develop a formal risk analysis without undertaking an exhaustive investigation of the existing levees. The time and money that would have to be expended on such investigations can be better spent by proceeding immediately with common-sense solutions.

The second factor is that a levee is not necessarily breached when the design flood is exceeded. Improvements to Delta levees are currently designed to accommodate water surface elevations resulting from a combination of tides and flooding that have a mean recurrence interval of 100 years, that is, a 100-year flood. These designs typically provide 1 foot of freeboard above that water surface elevation. But that does not mean that the levees in question might be expected to fail one in every 100 years, or that they have an annual probability of failure of 1 percent. It is likely lower than that, although it could in some circumstances be greater. If the 100-year water surface elevation is predicted correctly, and one assumes a simple Poissonian distribution, the probability of that water surface elevation being exceeded in 100 years is actually 63 percent. Current designs usually provide for 1.5 feet of freeboard although the UDLC and newer FEMA requirements are increasing this to 3 feet. If there has been no settlement of the levee crown and there are no waves, overtopping would thus have an even lower probability of occurrence. But since settlement is inevitable and wave action likely, then the real probability of overtopping becomes a function of effective monitoring and flood-fighting as water surface levels approach the design value. Additionally, a well-designed levee, with well-established vegetation, can withstand some overtopping without a breach occurring. In an idealized world, all the levees would be free of penetrations and low spots and all would be built to consistent elevations. Therefore, theoretically, if one levee overtops, then many levees would overtop and there would be multiple flooded islands. In reality, all levees are not equal. There is a greater chance that the ones with the most defects might be breached, but that can also be minimized by appropriate allocation of flood-fighting resources.

Similar, but greater, uncertainties impact whether there is a levee breach following an earthquake. If a levee is specifically designed for a certain level of loading, the levee does not necessarily fail in the sense that specified deformations are exceeded even if the design level of loading is exceeded. Geotechnical engineering design calculations normally err on the conservative side, so that if a formal design for earthquake loadings has been undertaken, the levee can be expected to deform less than the design anticipates should the design earthquake loading actually occur. Failures occur when there are gross oversights, like completely ignoring earthquake loadings or failure mechanisms, not because the calculations are in error. There is also uncertainty in the accuracy of the design loading itself. But, regardless of the amount of deformation and cracking that occurs under earthquake loadings, the probability of first overtopping and then failure is a complex function of the water surface elevations at the time of the earthquake and when repairs can be implemented. Thus, one of the considerations in the new Urban Levee Design Criteria, which require that if certain provisions are not met, the design has to allow for expeditious repairs. Following an earthquake, it might be possible to implement a variety of temporary measures, as well as permanent repairs. Some of these are discussed in Section 3.2. Such measures represent an extension of conventional flood-fighting to cover earthquakes as well.

This discussion leads to the suggestion that rather than trying to calculate precisely the relative risks faced by the various islands in the Delta and using that to prioritize funding, a much greater effort could be made to educate the Delta community and other interested parties as to the real vulnerability of the levees in a qualitative way, rather than a quantitative way, so that appropriate strategies can be developed to manage these risks. A range of possible strategies is discussed in Section 3. It also suggests that the continued use of a standards-based approach is likely more practical and effective than moving to a risk-based approach. To be useful as a planning and design tool, risk-based analyses have to take into account all of the uncertainties in the design and construction of levee improvements, as well as the human and organizational factors involved in flood-fighting and emergency response following earthquakes. That is quite a challenge and it is likely that the judgment of experienced engineers on these issues will provide more reliable answers for the foreseeable future. However, risk-based approaches might provide a good tool for evaluating progress in reducing the combined risks to Delta levees. In practice, as well as in academic settings, such analyses can also be helpful in identifying the factors that make the greatest contribution to risk so that measures can be taken to reduce their relative contribution.

Regulatory Issues

In addition to the physical challenges faced in the Delta, there are also man-made challenges that result from excessive bureaucracy and the politics surrounding these issues. Some of these are noted in this section.

Dredging

The Delta was largely created by dredging and for many years maintenance dredging was carried out, which aided flows and navigation as well as provided a source of fill for improving the levees. However, a surfeit of regulations has essentially brought dredging to a halt in the last 10 to 20 years. By some counts as many as 19 separate permits have to be obtained in order to dredge in the Delta. As a result of the additional expense that is generated by this regulatory process, borrowing on land is now the preferred alternative as a source of levee material. However, dredging is still required for maintenance and deepening of the deep-water ship channels. In addition, dredging is likely to be required to maintain some of the other waterways. It could also be used to generate material for selected levee improvements and will definitely be required for the major ecosystem restoration activities that are now planned for the Delta. The Sacramento District, USACE, is presently in the middle of an EIR process for deepening the Sacramento channel to 35 feet and is in a pre-EIR process for deepening the Stockton channel to 40 feet. These projects will generate 20-30 and 40-50 million cubic yards of spoils respectively. The Corps pays for the digging, but the ports are responsible for stockpiling and/or disposal of the dredged material. Historically the ports have charged end-users $1 per cubic yard for dredged material. If planned in advance, dredged material can be moved hydraulically at low cost for up to about 8 miles from the point of dredging. The water quality associated with this material is actually quite good and is in fact better than the water quality under the islands which is adversely affected by the presence of the peat. In addition to the possible use for reclaiming flooded islands or improving levees, this dredged material, if spread out over agricultural land, would both slow the loss of peat and improve water quality. USACE and other agencies are also embarked on a multi-year Long Term Management Strategy for Dredged Material in the Delta, the Delta LTMS.[8] The goal of the Delta LTMS is to develop a one-stop permit shop. Each agency (federal, state and local) would still be legally mandated to issue individual permits. The "shop" would consolidate that process by having well-defined permit recipes that if met, will allow for the issuance of each individual permit. This model exists in the Bay and it has been successful primarily because the revenues are there (from the shipping industry) and there are a sufficiently large number of projects to support full-time agency involvement. That has resulted in workable standards and processes that can be used to secure permits. Unfortunately, the Delta LTMS suffers from funding limitations and has shown little progress. But dredging is a good example of the kind of activity in the Delta for which there needs to be one-stop permitting of some kind, as discussed further below.

Vegetation

Whether or not to allow vegetation, at least on the waterside of levees, is a vexed question that is the subject of much debate both within USACE and between USACE, DWR, and other agencies. Since Hurricane Katrina, USACE has been insisting on strict implementation of their current national levee vegetation policy which prohibits woody vegetation on levees. Most fish and wildlife agencies are opposed to this policy. The situation is particularly acute in California where needed levee improvements have been blocked because levee vegetation provides critical habitat for species that are protected under both the State and federal endangered species acts. DWR has been pushing back on this new USACE policy and took the lead in setting up the California Levees Roundtable. The Roundtable effort was able to negotiate a temporary Central Valley Flood System Improvement Framework agreement. Intelligent provisions regarding levee vegetation are also included in the draft ULDC standard. However, in the Delta there is a need to go further since appropriate vegetation on the waterside of levees is a critical element of the Delta ecosystem restoration. Future Delta levee improvements should be undertaken with this in mind.

[8] http://www.deltaltms.com/

Bureaucracy

The sometimes rigid organizational structure and the slow pace of many of the multitude of bureaucracies that oversee or manage the Delta and levee system present a challenge. This is complicated by cross-purposes and philosophies of levee or Delta management. Limited resources of time and funding are expended on multi-year studies like CALFED, DRMS, or the Delta LTMS, yet these studies do not produce timely results. The joint USACE-DWR study that led to Bulletin 192-82 presents a case study of this dynamic. Although it was an excellent study, it has since been repeated two or three times, which has delayed achieving the goals set forth in that report. Those goals are only now close to being achieved—30 years later—by bringing all Delta levees up to the Delta-specific PL 84-99 standard. Keeping this in mind, it is suggested that the next round of improvements to the proposed Delta levees standard that addresses earthquakes, possible sea-level rise, and vegetation of the water side of the levees, needs to be implemented in the next five years, rather than another 30 years. If funding were in place, that effort could begin immediately. It does not require another joint USACE-DWR study or studies of the kind that have been proposed in the draft DWR Framework or that are currently being proposed in the staff drafts of the Delta Plan.

Lack of one-stop permitting

There is a clear need for a one-stop permitting agency for activities in the Delta such as dredging, levee construction, restoration of the flooded islands, and other eco-system improvement activities. The responsible agency would obviously need to coordinate with the many existing agencies that have a finger in the Delta, but creation of a one-stop permitting process would eliminate unnecessary delays and costs in making the necessary improvements to the physical Delta. There is also a need for unified Delta emergency management and levee improvement entities, and that is discussed elsewhere in this report.